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(54) Title: NOVEL DEVICE FOR SUBMERGED ULTRAFILTRATION

(57) Abstract: The device is a submerged ultra filtration membrane having capillaries that are packed in porous, supporting sleeves, which restricts possible damaging movements. An advantage of this is that the membranes may be more tightly packed. The outer side of the device can be kept clean by air scour and the inner capillaries by backwash and/or chemical cleaning. The device can typically be used in applications like the membrane bioreactor for the production of clean water from waste streams or rivers.

WO 2005/037414 A1

NOVEL DEVICE FOR SUBMERGED ULTRAFILTRATION

Summary

The device is a submerged ultra filtration membrane having capillaries that are (contrary to convention) packed densely in sleeves, which restricts possible damaging movements. The outer side of the device can be kept clean by air scour and the inner capillaries by backwash and/or chemical cleaning. The device can typically be used in applications like the membrane bioreactor for the production of clean water from waste streams or rivers.

Background of the invention

This invention is a membrane device that improves on membrane filtration of submerged elements. Submerged membrane filtration is a process whereby the permeate (a liquid containing components which should not be present in it) is drawn through a membrane element by a vacuum provided by a pump or by siphoning from hollow porous or semi permeable capillaries which are submerged in said permeate. By nature the separating surface is generally located on the outside of the capillary. The porous semi permeable capillaries usually employed, have a 100 nM to 1000 nM micro filtration range pore size, generally referred to as "micro filtration membranes".

One of the practical issues in membrane filtration is the problem of flux loss due to fouling of the membrane capillaries. In non-submerged filtration devices, where capillaries are in a fixed housing and where the permeation is generally brought about by pressure, this problem is generally counteracted by causing turbulence at the membrane surface, for instance by the high speed of the feed solution. In many cases, a backwash is also incorporated as part of the operation.

A description of a submerged device is given in US 5248424 by P.Cote et.al. where the capillaries are arranged in loose skeins and air bubbles are used to keep the capillaries clean for a longer period. An improvement on the above patent is given in US RE 37549 by Mailvaganan et.al.. Here the capillaries are arranged with a spacing between the capillaries in the potting to prevent touching of the capillaries at the capillary-potting interface. The capillaries are slightly longer than the distance between the headers and therefore can sway relative freely. The air bubbles exert forces which cause a scrubbing action to maintain a clean membrane surface.

The state of the art submerged devices however pose some problems which are solved by the present invention.

The devices according to US 52448424 and US RE 37549 as well as US 6325928 have free moving membrane capillaries. This means that the material of the capillaries has to be very flexible. This reduces the number of polymers to be used for manufacturing the membrane considerably, because materials which may be vulnerable towards fatigue breaks due to the flexing cannot be used. The use of air bubbles for cleaning also exerts considerable force on the capillaries. This may also cause membrane breaks. One way of preventing the capillaries from breaking is to use a reinforcement in the capillary as described in US 5472607, especially on the area at the interface of potting and free moving where the capillaries are vulnerable.

In US RE 37549 measures like adding an extra soft layer of polyurethane are described. All these measures however add cost to the device.

The forces on the capillaries caused by the air bubbles can also be distributed over more membranes so as to reduce stress on the individual capillaries as well as movements at the potting capillary interface by fixing and or

supporting the capillaries with fibres as described in US 5480553 and 5922201. It is obvious that preparing a woven structure also adds to complexity and cost of a system.

Another problem in the existing designs is that course material present in the feed solution, like hair can be trapped between the membranes because of the movement and spacing of the membranes. This is generally very difficult to remove.

Summary of the invention

With this submerged membrane filtration device, where a bundle of capillaries is held together by a open sleeve or casing, very good results have been obtained. By reason of the capillaries being densely packed in this configuration, it has been shown that coarse materials like hair are filtered by the sleeve or outer ring of capillaries so that these materials cannot intrude in the inner section of the membrane element. The sleeve and outer ring of membranes is kept clean by air bubbles. This keeps the suspended solids in a state of suspension and simultaneously maintains a feed flow along the elements containing the capillaries.

The device's relatively densely packed membrane bundles supported by the sleeve not only prevents practically all forces, especially longitudinal forces, but also prevents movement of the membranes at the capillary/poting interface. Consequently, no measures to protect the capillaries from breaking are necessary. Furthermore the capillaries do not need to have the extra length between the headers. They may be of the exact length and are restricted in movement.

The use of densely packed bundles of capillaries also simplifies the potting operation , because capillary/capillary contacts are permissible, so one does not have to take care of spacing between the capillaries. The described invention also allows a very high packing density in the element , providing a very high surface area in the device.

Several of the devices can be combined into a module to generate a filtration surface area which is a multiple of the number of devices used. In larger systems it is obvious that multiples of modules can be used to achieve the filtration area required.

The distribution of air bubbles between the elements can be achieved by known methods. Since the unwanted forces on the membranes are prevented, the choice of membrane materials is enhanced. Materials that would otherwise give rise to fatigue break due to the continuous movement in the state of the art elements can be successfully used in this design. This implies for instance that the membrane described in US 5076925 by Koenhen et.al. can be used. Also the length between the header is not restricted in any way when the design according the invention is used. The elements can also be used in both the vertical and horizontal ways.

With current technology, the capillaries further inside the bundle are not reached by the air bubbles. Consequently, the cleaning has to be effected by regular backwash. This backwash is effective only with membranes which have a clean water productivity of less than 1500 l/m2/h/bar. This is because the backwash water has to be fed through the bore of the capillary and for a certain length one has to take account of pressure drop. In a micro filtration membrane with a pore size of 0,5 micron the flux can be as high as 50000 l/m2/bar.

Using such a membrane would mean that because of the limited amount of water that can be fed to the bore, all the water may pass through a small portion of clean membrane while the rest of the membrane remains fouled. This phenomenon can be compared with the channelling effect known from multi-media filters.

In the present invention it has been shown that an element with a bore size of 0,8 mm and a diameter of 110 mm and a length of 1.5 m , fitted with capillaries with a clean water flux of 800 l/m2/h/bar can be successfully cleaned over the total length by backwashing during a long term trial in a municipal waste water application.

The restriction in clean water flux adds an additional advantage to this invention because of the fact that known membranes possessing the flux characteristics are generally to be found in the ultra filtration range of pore sizes. This means that besides a total removal of bacteria there is also a very substantial removal of virus particles.

The importance of this fact is obvious when the device is to be used in waste water treatment.

Detailed description of the invention

A bundle of capillaries 1 is closely held together by a sleeve 2 of a very open material. The sleeve can be made of rigid material such as polypropylene or of a flexible netting material. These materials are very well known in the production of cartridge filters. Alternatively, woven or non-woven cloth may be used. Suitable sleeves can be obtained from companies like Netlon or NSW.

The openings in the sleeves should preferably be between 0,3 and 10 mm where the porosity is typically in the order of 50% or higher.

The ends of the bundles are potted in such a way that a part of the sleeve 2 is in the potting material. This ensures that movement of the capillaries at the potting interface is impossible. The other end of the potting 3 can be cut off so as to expose the open ends of the capillaries. Headers (single or multiple modules) can be prepared according to procedures well known in the industry and described in several patent descriptions. Schematic examples of such modules are given in figs 2 and 3.

Spacing of the elements in the modules allows air bubbles to pass along the elements, maintaining suspension of suspended solids and cleanliness of the sleeve and outer ring of membrane capillaries.

The inner capillaries can be cleaned either through backwash or by chemical cleaning. During the backwash the air bubbling remains in function to sweep away suspended solids released from the capillaries during such backwash.

The diameter of the bundle and therefore of the device can be chosen in such a way that the hydraulic resistance (pressure drop) for the feed to flow to the centre of the bundle is not detrimental to the flux of the capillary, i.e. the transmembrane pressure in the centre should be adequate to produce sufficient water.

The optimum bundle diameter therefore is a function of the desired flux and fibre diameter. This of course is also the case for efficient backwash. We have found that with capillaries with a diameter of 1.2 mm, the best bundle diameter is between 1 and 20 cm. With capillaries of 2.5 mm outer diameter the optimum element diameter is between 5 and 40 cm.

The length l of the devices is preferably more than 0.5 m . The filtration area is extended linearly with the length of the devices so that the length can be optimised with reference to the hydraulic pressure loss in the bore of the capillaries. Typically, a length of between 1 m and 2 meters is currently the most appropriate.

In another embodiment, the device described can be included in a pressure tank where the driving force for permeation is pressure. An example of such a tank with means of air scouring is given in Singapore patent 200003859-6 by Dr. C.H. Krishnamurthi Rao et.al.

Example

A membrane bioreactor module containing 8 elements with a diameter of 110 mm and a length of 1500 mm according to the description was entered into a tank containing sewage. Air was bubbled from the bottom. Further details are given in table 1

Table 1

DETAILS OF MBR DESIGN PARAMETERS		
MOC OF POLYMERIC MEMBRANE	**:**	**PES**
MWCO	**:**	**150-250 KD**
MBR DESIGN CAPACITY	**:**	**1000 LPH**
MEMBRANE AREA	**:**	**40 M2**
DESIGN FLUX	**:**	**25 LMH**
MODE OF OPERATION	**:**	**OUT TO IN**
OPERATION DETAILS		
FLUX	**:**	**20 - 30 LMH**
DRIVING FORCE	**:**	**VACUUM MODE**
BACKWASH INTERVAL	**:**	**20-30 MINUTES**
BACKWASH DURATION	**:**	**30 SECONDS**

CHEMICALS CLEANING FREQUENCY : ONCE PER WEEK
RECOMMENDED CLEANING CHEMICAL:HYPO/CAUSTIC/CITRIC

Results of the trial are listed in table 2. As can be seen very good results have been achieved and at stable flux of 20-30 l/m2/hr.

Table 2

S.NO	PARAMETERS	UNIT	MBR FEED	MBR PRODUCT	% OF REDUCTION
1	TURBIDITY	NTU	40	0.5-1.0	96.5
2	SUSPENDED SOLIDS	PPM	6,400 as MLSS	3	99.9
3	COD	PPM	245	61	75
4	BOD	PPM	68	9.0	87
5	OIL AND GREESE	PPM	2.0	ND	90(assumed)
6	AMMONIA	PPM	42	18	42
7	PHOSPHATES	PPM	7.5	3.3	56
8	IRON	PPM	0.1	NIL	100
9	SILICA	PPM	106	102	3.7
	BECTERIOLOGICAL TEST				
10	COLIFORM BACTERIA PER 100 ML	-	$5.42X 10^6$	Not detected	100

Claims

What we claim is:

1. An ultra filtration device for withdrawing permeate essentially continuously from a fluid containing suspended solids, while increasing the concentration of suspended solids therein by a driving transmembrane pressure caused by a vacuum, said membrane device including:
    A. A multiplicity of capillary membranes confined in a porous sleeve restricting the movement of the capillaries.
    B. A first header and a second header in transversely spaced relationship with at least one header within the fluid containing the suspended solids.
    C. At least one header with the open ends of the capillaries extending in the header to a permeate discharge.
    D. A gas distribution means near the lowest point of the total assembly, adapted to generate bubbles flowing around the device which keeps the sleeve and exposed portions of the outer capillaries clean.

2. The membrane device of claim 1 whereby the capillary membrane is an ultra filtration membrane of a polymeric material with a cut-off of between 3000 Dalton and 200.000 Dalton.

3. The membrane device of claim 1 where the diameter of the capillaries is
between 0.1 and 5 mm..

4. The membrane device of claim 1 wherein the device is placed vertical.

5. The membrane device of claim 1 wherein the device is place horizontal.
6. The membrane device of claim 1 wherein a cleaning of the majority of capillaries is achieved through backwashing or by chemical cleaning.

7. A module consisting of several membrane devices according to claim 1 to form a module.

8. A system according to claim 7 in which the gas distribution system is separate from the module.

9. An ultra filtration device for withdrawing permeate essentially continuously from a fluid containing suspended solids, while increasing the concentration of suspended solids therein by a driving transmembrane pressure caused by a pressure, said membrane device including:
    A. A multiplicity of capillary membranes confined in a porous sleeve restricting the movement of the capillaries.
    B. A first header and a second header in transversely spaced relationship with at least one header within the fluid containing the suspended solids.
    C. At least one header with the open ends of the capillaries extending in the header to a permeate discharge.
    D. A gas distribution means near the lowest point of the total assembly, adapted to generate bubbles flowing around the device which keeps the sleeve and exposed portions of the outer capillaries clean.
    E. A pressure vessel to contain the device or a multiplicity of devices.

10. The membrane device of claim 9 whereby the capillary membrane is an ultra filtration membrane of a polymeric material with a cut-off of between 3000 Dalton and 200.000 Dalton.

11. The membrane device of claim 9 where the diameter of the capillaries is between 0.1 and 5 mm..

12. The membrane device of claim 9 wherein the device is placed vertical.

13. The membrane device of claim 9 wherein the device is place horizontal.

14. The membrane device of claim wherein a cleaning of the majority of capillaries is achieved through backwashing or by chemical cleaning.

15. Membrane devices according to claim 1 and 9 where the air scouring is continuous.

16. Membrane devices according to claim 1 and 9 where the air scouring is discontinuous.

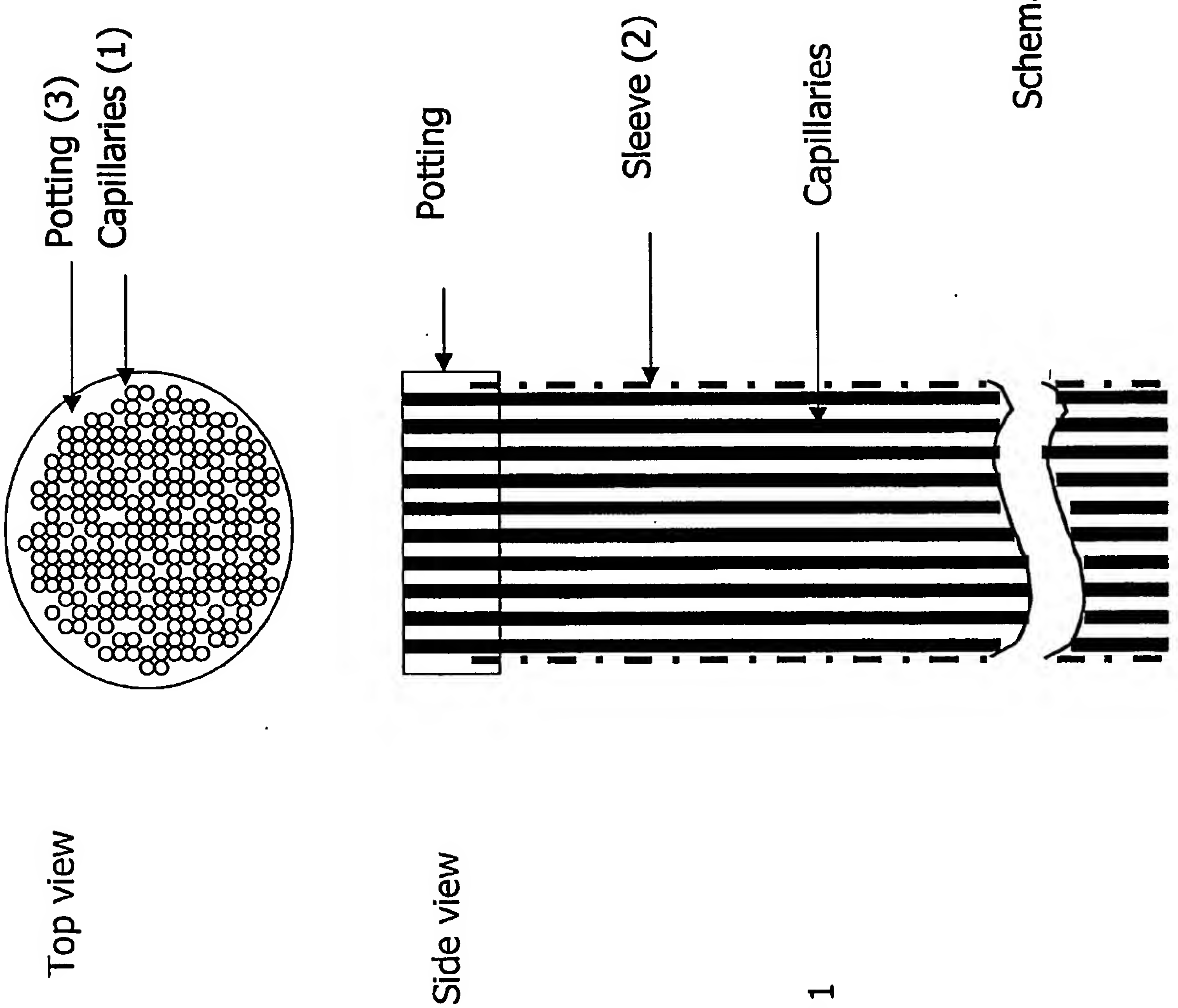
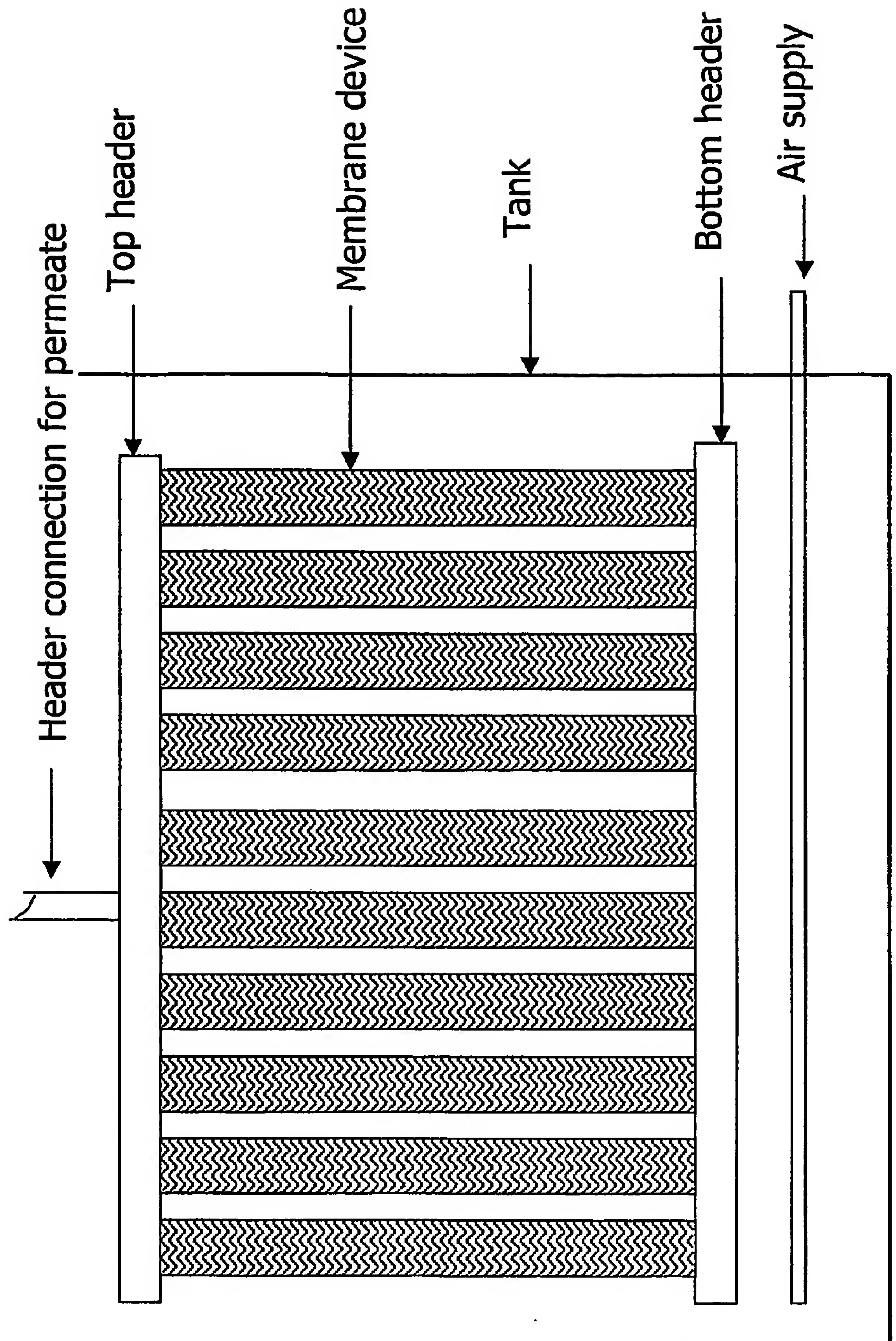


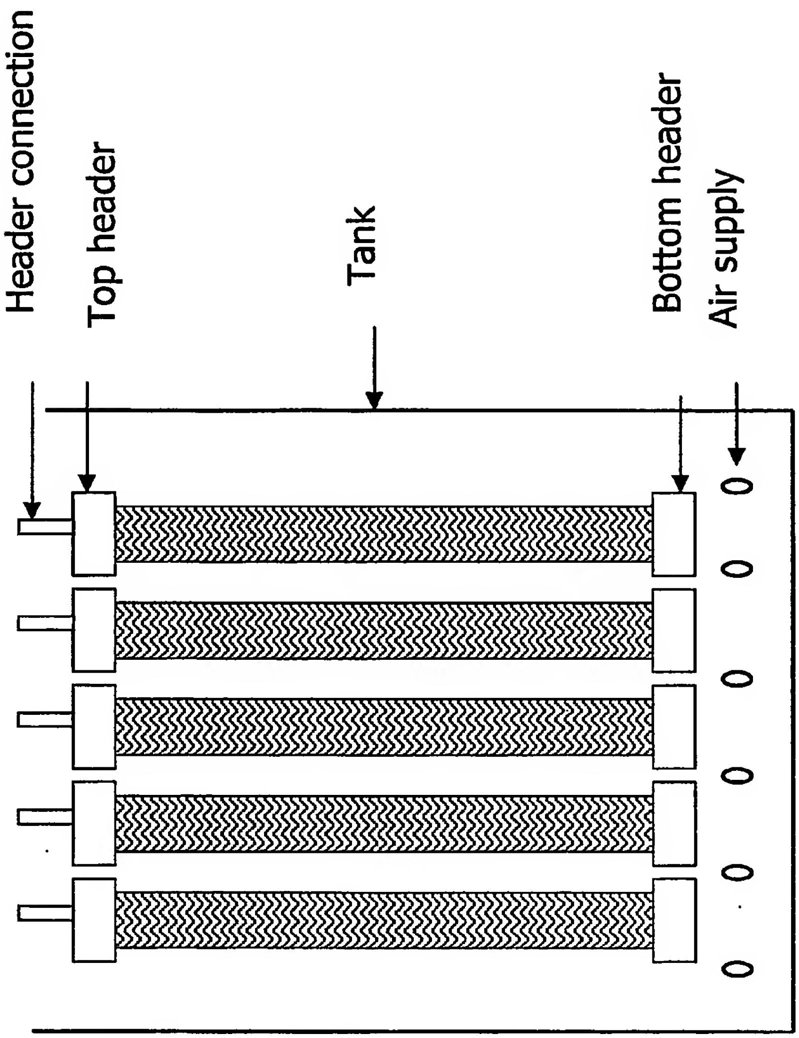
Figure 1

Schematic of membrane device



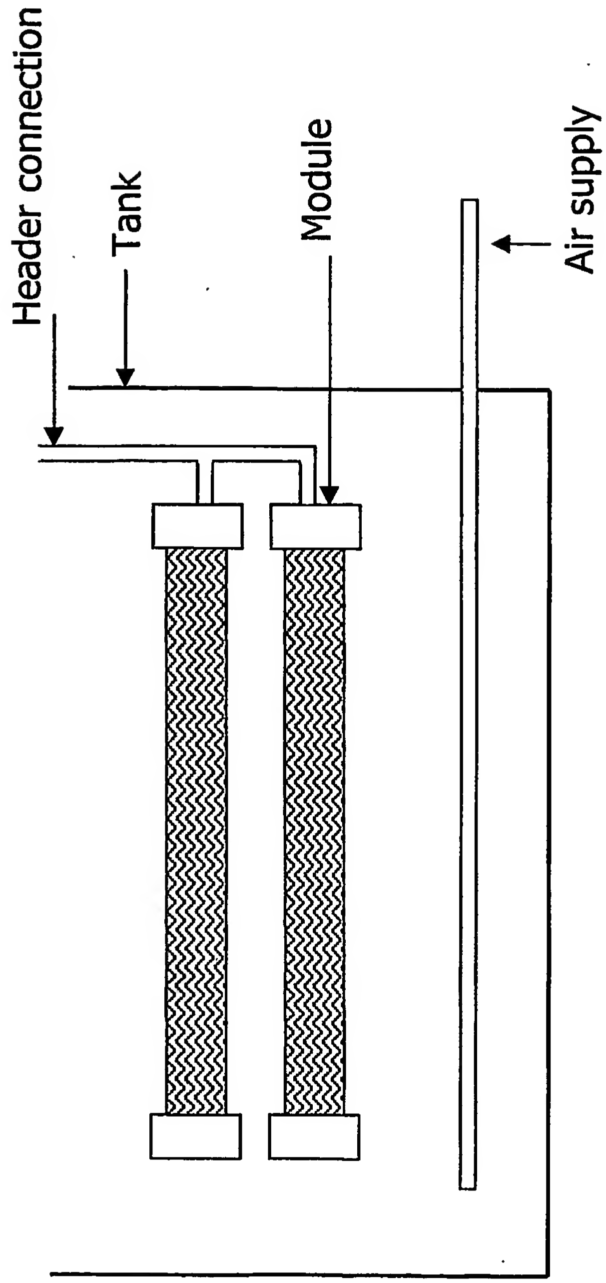
Schematic of module with several devices

Figure 2



Schematic with several modules

Figure 3



Schematic of horizontal installation

Figure 4

INTERNATIONAL SEARCH REPORT	International application No. PCT/SG03/00249

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. 7: B01D 63/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Derwent DWPI: IPC B01D 69/04, 69/08, 69/10, 63/02, 63/04, 61/18 with keywords SLEEV, CYLIND, BUBBL, GAS, SCOUR, ULTRAFILT

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 89/00880 A1 (MINNTECH CORPORATION) 9 February 1989 Whole document	1-16
A	EP 1180391 A2 (SANYO ELECTRIC CO., LTD) 20 February 2002	

☐ Further documents are listed in the continuation of Box C ☒ See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 November 2003	3 - DEC 2003
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer MATTHEW FRANCIS Telephone No : (02) 6283 2424

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/SG03/00249

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
WO	8900880	EP	0381666				
EP	1180391	CN	1344582	JP	2002058968	US	2002070157

END OF ANNEX